

Mini-micro hydro power technology (MMHP) Status Report - India

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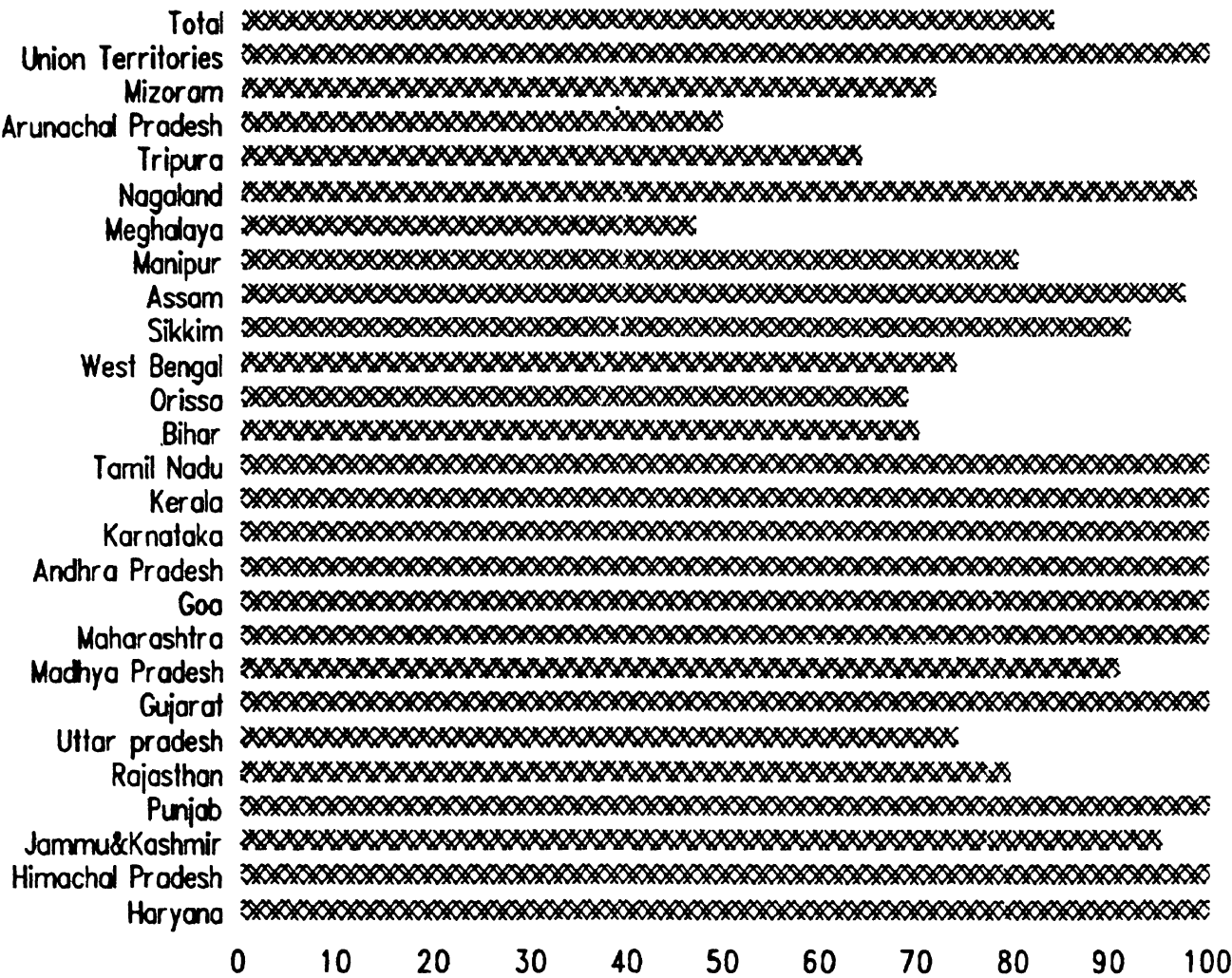
Energy scenario in India

In India, commercial fuels contribute 60% of the total energy while the rest is provided by the non-commercial biomass fuels. Over 60% of the commercial energy is consumed by industry and transport sectors. Diesel and electricity are the main sources of energy in the agricultural sector, mostly for irrigation. Urban domestic sector depends mainly on commercial fuels like kerosene, LPG and electricity. Fossil fuels, thus, feature prominently in the country's present energy mix. However, the resource endowments in terms of these fuels namely coal, oil and natural gas are very poor in the country. They constitute only about 6%, 0.6% and 0.6% of the total world resources, respectively. Among the primary sources, coal and hydro power are relatively abundant but their exploitation is constrained by factors such as poor quality of coal, environmental concerns such as pollution, submergence and displacement, problems of river sharing among different states, etc. Consequently, as much as one-third of the total export earnings of India are spent on importing oil products, burning of whom is known to have serious implications on the environment and the climate.

On the other hand, the non-commercial fuels such as firewood, crop residue and animal dung contribute about 40% of the total energy, more than 80% of which is consumed in the rural areas. Household is the most portentous sector in the rural areas accounting for over 75% of the energy consumption. Agriculture is the other significant energy consuming sector in the rural areas with industry and transport being marginal. Continuing dependence on non-commercial fuels in these areas is also leading to a variety of environmental problems such as natural resource degradation and adverse impacts on health.

Perhaps, one of the major steps taken towards all round development of the nation was the rural electrification programme (REP). Through extension of the power grid to rural areas, the programme strives to make electric power available to the rural consumer for lighting, irrigation and various other applications. REP has been implemented in India as a thrust programme for almost two decades, and by now, 84.1% of the total villages in the country are reportedly electrified.

Number of electrified villages (%)



This percentage, however, could be misleading since the number of households actually having connections is reportedly quite low, just 27% of the total 130 million rural households, according to one estimate. Extension of transmission lines over long distances all over the country involves significant transmission losses. Further, since demand is much in excess of generation, rural areas tend to get a much lower priority against urban and industrial centres on event of shortfall in supply or breakdown in generation. Consequently the quality of power supply in many rural areas is erratic and poor. The severity of the situation is further amplified in case of hilly and mountainous regions of the country where laying of transmission lines is not only an arduous task in logistical terms, but also economically inviable: costing as much as thrice the amount it may require in the plains. Even today, large parts of remote, hilly states, particularly those in North-east remain unelectrified.

Thus, the overall energy consumption pattern based on fossil fuels and non-commercial fuels appears unsustainable, and if continued in the long run, is likely to lead to serious environmental crisis in the future. Moreover, fossil fuels, being non-replenishable, will be available only for a finite period (till their reserves last). Therefore, it has become imperative to examine, develop and implement technologies based on ecologically sustainable and economically viable alternatives to meet the fast growing energy demand in the country. The only available options which immediately strike one's mind when thinking on these lines are renewable energy technologies (RETs). Based on replenishable sources such as hydro, solar, wind and biomass, these technologies have been receiving close attention from various quarters because of their potentiality of becoming possible alternatives. Though a number of RETs such as mini-micro hydel power (MMHP), biogas, gasifiers, photovoltaics, solar thermal systems, wind, etc. have been disseminated in India for more than two decades by now, their impact has been minuscule as most of them were implemented on a pilot scale under the patronage of the government. Table 1 summarizes the total installed capacity in terms of different renewable energy technologies in the country.

Table 1: Deployment of renewable energy technologies (till March 1993)

Programme/technology	Cumulative installation
Mini-microhydel systems	93.44 MW
Windfarms (power generation)	53.68 MW
PV power plants	408.86 kWp
Family-size biogas plants	1.76 million nos.
Improved cookstoves	14.5 million nos.
Domestic solar water heaters	12 517 nos.
Industrial solar water heaters	6142 nos.
Solar cookers	288 028 nos.
Photovoltaic (PV) water pumps	756 nos.
PV community lights/TV	719 nos.
PV domestic lighting units	14 594 nos.
PV street lights	29 198 nos.
Wind pumps	2811 nos.

Source: Overview of Programmes, July 1993, MNES, New Delhi

As can be seen from the table, the penetration of RETs has, with the exception of biogas and improved stoves, been quite low. The high initial costs associated with their installation, especially when compared to conventional fuels which enjoy large hidden subsidies, has proven to be the main constraint in widespread promotion of these technologies. Given the doubts persisting about their economic viability, investment in the renewable energy sector has also been low. For instance, during 1980-92, cumulative government expenditure in the sector was just IRS 11.55 billion compared to IRS 812 billion in power sector, IRS 335 billion in petroleum sector and IRS 158.5 billion in coal sector. In the VIII Five Year Plan (1992-97) of the government, too, the allocation for RETs has been an insignificant 0.8% of the total budget for the energy sector.

However, with the growing concern for sustainable development, efforts towards promotion and commercialization of RETs have been steadily growing. Some of the technologies such as wind, mini-micro hydel and photovoltaics have proven their techno-economic viability, especially in situations where conventional fuels are expensive or inaccessible. Given this evolving scenario, a new strategy has been put into implementation by the Ministry of Non-conventional Energy Sources (MNES) in the latter part of 1993, which provides thrust on promoting RETs through commercial enterprise rather than state subsidies. A separate financial institution, Indian Renewable Energy Development Agency (IREDA) has also been set up to provide soft loans to private manufacturers and entrepreneurs who invest in the renewable energy sector. There has also been substantial international assistance from the World Bank and Global Environmental Facility to accelerate the process of commercialisation of RETs in India. Mini-micro hydro power (MMHP) technology is one of the RETs which has come to the fore in this new dispensation as a reliable source of rural electrification.

Mini-micro hydro power (MMHP) systems

MMHP is one of the oldest exploited renewable energy sources in India which has been in existence since the beginning of the 20th century. But even much before that, the technology had been used in the villages in the form of water wheels to provide motive power to run grinders, etc. MMHP enjoys several advantages as an energy source:

- It is a reliable, mature and proven technology.
- It can be operated in decentralised mode as a stand alone system which can meet the lighting and power needs of a remote, inaccessible village. Or else, the system can be synchronised with the conventional grid to strengthen the supply system.
- Low capacity systems can be installed on even small water bodies of with sufficient flows provided the head of the fall is at least 2 m and above. Thus, they can be effective even for small applications with low peak demand.
- It requires low initial investments and has short gestation periods.
- It does not entail construction of large dams or reservoirs, and avoids environmental concerns such as loss of flora and fauna due to submergence, deforestation, displacement of people, etc. usually associated with large hydro power stations.
- It substantially reduces the transmission losses.
- It is environmentally benign; no pollution or waste generation.

Thus, it is no wonder that MMHP has come to be considered a major technology for the hilly, remote regions which can play a significant role in the overall upliftment of these areas.

Classification of MMHP systems

MMHP systems cover a wide range of sizes and capacities. On different occasions they have been classified or grouped into different sub classes. In India, however, the most widely adopted definition is as follows¹:

¹In this report the phrase MMHP has been used to cover all three categories, upto 15 MW.

Micro hydro	less than 100 kW
Mini hydro	100 - 2000 kW (unit size upto 1 MW)
Small hydro	2 - 15 MW (unit size upto 5 MW)

Presently, systems upto 3 MW capacity come under the purview MNES. Projects with capacities between 3 MW upto 15 MW are dealt with by the Ministry of Power.

Typical components of a MMHP system

Diversion structure

A suitable structure in the form of a trench weir, dam (permanent or temporary) or any other obstruction is generally constructed at the headworks of the stream from where the required quantity of water is to be diverted for power generation.

Intake structure

This structure is designed to admit the diverted water into the power channel. A suitable regulatory mechanism is usually provided at the intake by means of which flow of water into the power channel can be controlled or completely shut off.

Power channel

The power channel starts from the headworks (beside the diversion structure) and is designed to carry the diverted water to the forebay or reservoir which is usually directly above the power house. Predictably, the slope of this channel is much lesser than the stream itself due to which, at the location of the power house, it is at a much higher elevation. Usually the channel has to wind through the hillsides on the bank of the stream and occasionally it may have to pass through tunnels and aqueducts (flumes) which may have to be constructed due to topographical reasons. At a number of locations along the course of the power channel, strainers are installed to block floating debris. Cleaning of these strainers is generally done as a matter of routine. Also, at appropriate distances, the power channel is provided with outlets which can be useful in emptying a certain reach of the channel during maintenance.

Desilting tank

This is an essential component of any MMHP installation primarily consisting of a wide tank which enables the water to remain relatively still thus allowing the silt to settle

down. By means of suitable mechanisms it is possible to remove the deposited silt on a regular basis. An overflow arrangement is usually provided to allow excess water to fall back into the channel. A well designed desilting tank can be very effective in protecting the turbines and enhancing their life and performance.

Forebay/reservoir

A forebay or reservoir acts as a final settling area before the water enters the penstock. The reservoir capacity is designed to take care of sudden increases in turbine demand and has a spillway to reject excess water on event of sudden decrease in turbine demand. Usually there is a valve to control the flow of water at the entrance to the penstock. The orifice at the entrance to the penstock is guarded by a mesh or strainer.

Penstock

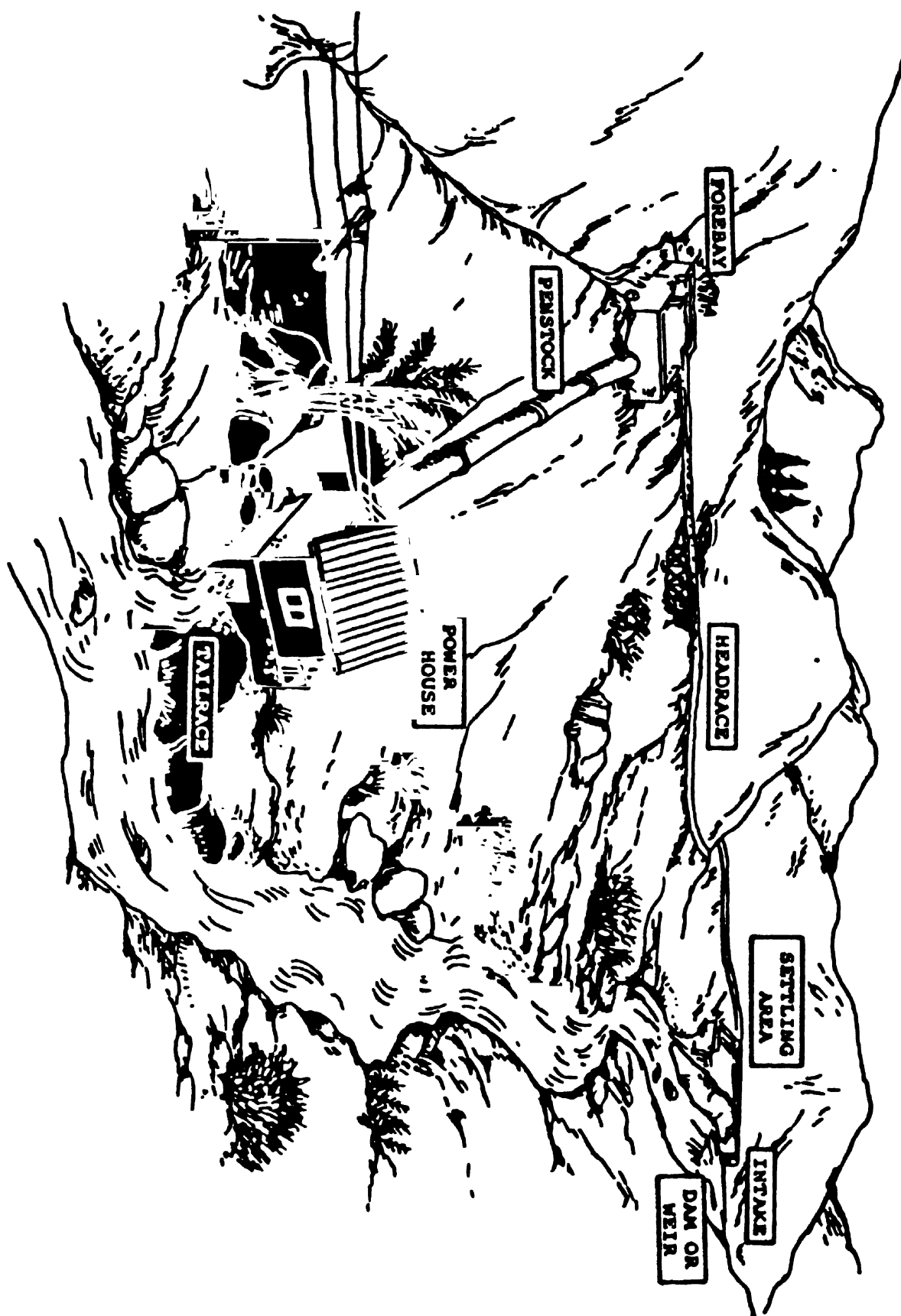
It is a conduit through which water drops down from the reservoir to the turbine. It is generally made of steel pipes of appropriate diameter and wall thickness. The inclination is as close to vertical as possible subject to the local topographical conditions. Vent pipes are provided at suitable locations to release excess pressure and avoid penstock rupture due to sudden surges. Valves are installed at the entrance to and exit from the penstock for attaining control on the flow.

Power house

It is a building which houses the machinery viz. the turbines, alternators, governors, synchronization circuits, safety mechanisms, distribution components, etc. Sometimes, there is also a workshop for attending to routine maintenance jobs.

Turbine

It converts the energy of flowing water into mechanical energy and rotates the alternator. The primary element in a turbine is the runner which is present on a rotating shaft and has a number of vanes. There are several kinds of turbines depending upon the shape of the runner and casing. Some of these are discussed later in the report. In general, for the same output, high head turbines tend to be smaller in size and more compact than low head ones.



Components of a hydroelectric scheme.

Generator/alternator

Induction as well as synchronous generators are used for production of electric power. Usually, a flywheel of suitable size is installed between the turbine and alternator. The generators may be of self excited or externally excited type. In the latter, another small dynamo or generator (using permanent magnets) is coupled separately to the same turbine.

Governor

The function of a governor is to cut off the water supply to the turbine in case of a sudden tripping of load or to suitably alter it in case of variations in the load. The governors employed in most installations in India are of mechanical (oil pressure) type which operate by maintaining constant RPM of the system. Recently, electronic governors have also been introduced.

Tail race

The tail race is a channel which directs the outcoming water from the turbine back to the stream. In case of multiple turbine units, the outlet channels of all the constituent turbines of the powerhouse either join together or empty into a single channel to form a common tail race.

Technologies for power generation

MMHP systems are generally of two basic types viz. *run of the river* and *canal drop* schemes. The former is usually located on a river or its tributary whereas the latter can be found on irrigation canals and water courses. Canal drop installations are generally of low head type, the head varying from 3 metres to 30 metres. Run of the river installations usually have higher heads much in excess of 30 m because the sites are in the mountainous regions. Thus, low head systems are usually in the plains region while high head installations are mostly in the Himalayan belt.

As regards the electro-mechanical equipment, there exist different types of turbines with a number of features. Based on the principle of energy extraction, there are two kinds of turbines viz. impulse turbines and reaction turbines. Impulse turbines use the velocity of water to drive the runner while reaction turbines use the pressure of water. Depending upon their design and constructional features, they are further subdivided into a number of sub categories as illustrated in Figure 2. Mostly synchronous generators are used on mini-micro installations. At a few places and particularly for smaller installations, induction generators may also be used.

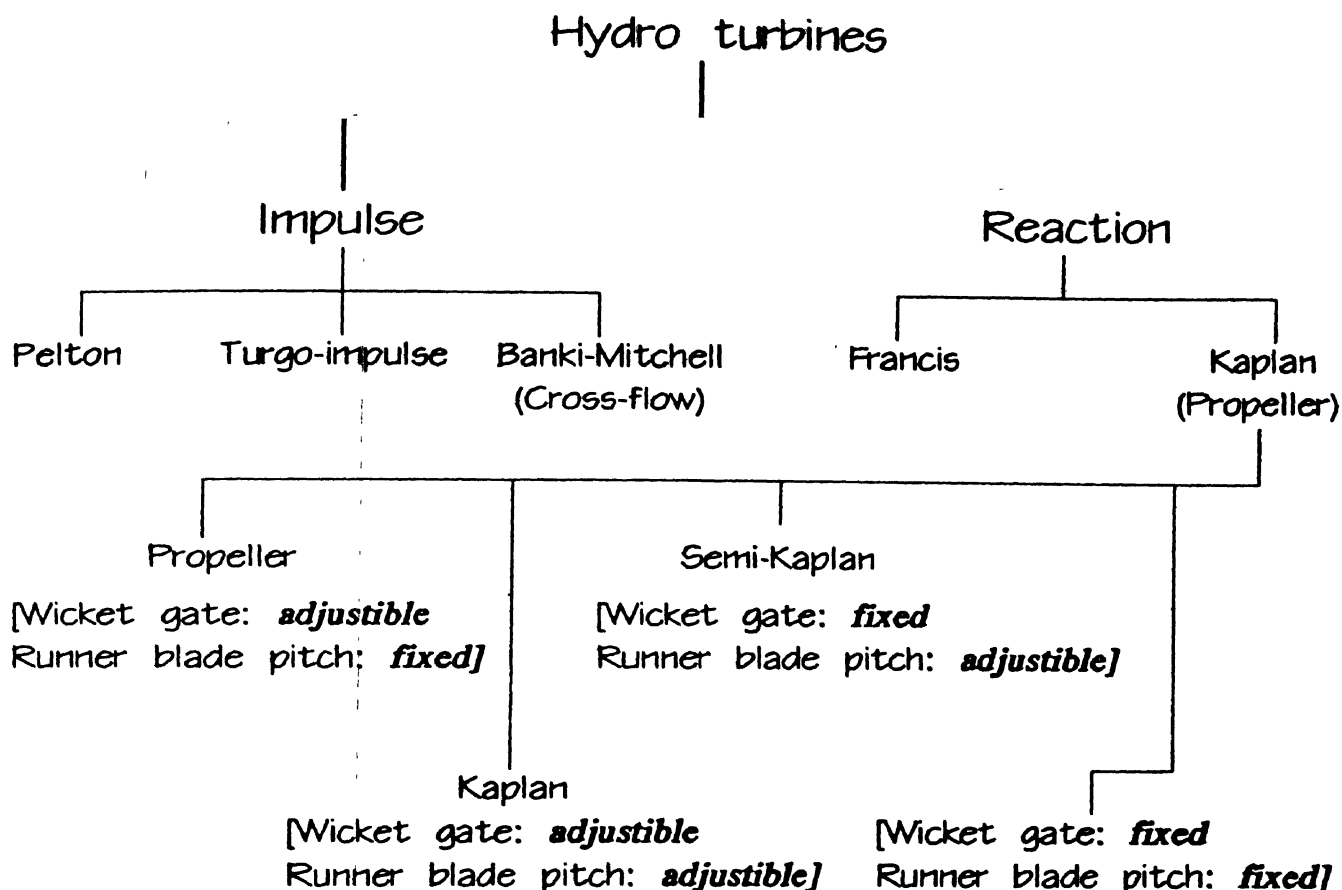


Figure 2 Classification of hydro-turbines used in MMHP projects

Economics of MMHP in India

The general rule "smaller the size, higher the cost" also applies to mini-micro hydro technology. However, there are a number of measures which can be adopted to reduce the costs of installation and operation of MMHP plants. Unfavourable conditions with respect to economics, usually associated with MMHP are:

- High specific cost (i.e. per kW installed capacity)
- Low load factor particularly when used in decentralized/ stand-alone mode of operation.
- Little or no peaking capacity
- High operation and maintenance cost.

Installation costs of MMHP can vary widely from about IRS 5000 per installed kilowatt to more than IRS 80 000 per installed kW. Generation cost for MMHP installations also varies substantially due to a number of factors such as the distance, down time, natural/climatological factors, etc. It is, however, more than IRS 2 per kWh for installations below 3 kW. For MMHP installations above 3 MW and large hydro, the generation cost varies from IRS 0.72 to IRS 1.45 per kWh. Thus, MMHP generation

cost for units having an installed capacity below 3 MW is over 10% higher than large thermal power plants which cost from about IRS 1.38 to IRS 1.85 per kWh.

The latest MNES approved norms for capital costs of MMHP schemes and the generation costs are as follows:

• **Capital costs**

- Canal based schemes - IRS 35 to 50 million
- Schemes in hilly areas/NE region - IRS 50 to 60 million

• **Cost of generation**

- All schemes - IRS 1.50 to 3.50 per kWh
(depending upon the terrain and available head)

History of MMHP in India

Early installations

MMHP technology was introduced in India shortly after the commissioning of the world's first hydro-electric installation at Appleton, USA in 1882. Early hydro power installations were of MMHP category only and played a crucial role in the development of hydel resources in general. The 130 kW plant in Darjeeling in the year of 1897 was the first ever MMHP installation in India. Few other powerhouses belonging to that period such as Shivasamundram in Mysore (2 MW, 1902), Galogi in Mussoorie (3 MW, 1907), Chaba (1.75 MW, 1914) and Jubbal (50 kW, 1930) near Shimla are the MMHP stations still known to be working at full capacity.

Power generated from these plants was used primarily for lighting purposes in important towns. The Chaba project was also meant to supply drinking water to Shimla town. Interestingly to meet the power and lighting requirement for mining work of Kolar Gold Field, the Shivasamundram power plant was installed 160 km away and perhaps it was the first of its kind in the world with such a long DC transmission line. Today, the capacity of many of these installations has been further upgraded: for instance, the installed capacity of Shivasamundram is now 42 MW and that of Darjeeling is 800 kW.

Most of these powerhouses utilized the high head available at the sites. Impulse turbines were generally preferred in such conditions. It is interesting to note that the original equipment installed at many of these early MMHP sites are still working in good condition. Low head MMHP installations, on the other hand, came into being rather late: around 1925-30. A series of falls on upper Ganga Canal were exploited for such installations. Kaplan type of propeller turbines were preferred at these sites since they had been successful in European countries. With the passage of time the capacity of some canal schemes have been upgraded many times resulting in larger installations.

The major handicap for small hydro electric stations in the early days was that technology of high voltage transmission lines had not been developed. Since the distance of these installations from the load centre was usually substantial, heavy line losses were incurred. With the development of high voltage transmission lines in the early part of the 20th century a shift also occurred from mini-micro hydro plants serving local electricity markets to larger scale plants feeding into extensive distribution grids.

Propagation and expansion of MMHP in India

The spread of MMHP in India has so far been restricted to those areas where alternative sources are not available. Thus, the development was confined to the small hilly streams in the Himalayan region covering Jammu & Kashmir, Himachal Pradesh, Garhwal and Kumaon in Uttar Pradesh, Darjeeling in West Bengal, Arunachal Pradesh, etc. Later, some low head installations came up on a number of canals on the Ganges between 1930 and 1950 before the proliferation of HT transmission lines. Some installations were also implemented in the seventies on the canals of Kosi and Gandak rivers using heavy generating plants of bulb type. With availability of alternative options such as thermal and diesel and with the spread of transmission lines, MMHP development took a back seat. During 1960s some stations were installed in the hilly regions of UP to serve isolated areas.

Performance of early systems

The performance of the power stations installed in the early days was by and large successful, particularly in terms of its expected life. The installed capacity of some of the stations has since been upgraded with the intention of exploiting the full potential available at the site. Nevertheless, a few stations had to be abandoned because of a number of reasons.

Those stations which are connected to the grid, are performing well. Isolated stations in remote and hilly terrain tend to have a low load factor and are, therefore, not able to utilize their capacity and potential to the maximum extent. Some of the stations require replacement of generating equipment. Only such stations that are located in areas where there is no other option for power generation tend to evoke the concern of SEBs as far as maintenance or replacement of equipment and civil works is concerned. Several of the early installations have functioned much beyond their design life and require modernization. According to rough estimates about 50 MW worth of equipment may be ready for replacement immediately in Jammu & Kashmir, Uttar Pradesh, Arunachal Pradesh and West Bengal.

Government efforts

Development of MMHP in the country was relatively low key in the first half of the century. The pace stepped up only after independence, by which time, technology for exploiting large hydro potential was available and efforts were concentrated on major hydro projects.

Implementation efforts before independence during the British rule were mainly directed towards meeting the local needs of important towns in the hills and small industries. Making power available to the rural areas was not a major concern of the utilities. Wherever necessity was felt, preference often went to the cheapest schemes in terms of capital cost viz. diesel generating sets. After independence, except for a few installations, the newly formed state governments and state electricity boards focussed mainly on large hydro or thermal projects to cater to the power requirement that arose due to rapid urbanisation and change in the standard of living¹.

During the IV Five Year Plan, rural electrification was accorded top priority. Even then, no comprehensive plans were drawn up for the installation of MMHP stations as an integral part of rural electrification programme. The available options for meeting the demand for electricity in rural areas were as follows:

- Expansion of grid network to cover all areas
- Installation of diesel generating sets
- Installation of MMHP projects harnessing the small perennial streams which are in abundance in rural hilly areas

In areas where other options of electrification were available, the MMHP alternative was often discarded on account of relatively higher costs involved and due to the fact that they were not very attractive as compared to large thermal and big hydro options. But such decision making did not, perhaps, adequately consider:

1. High transmission losses in the conventional grid
2. Very long gestation periods for large hydro power stations.
3. Slippage *vis-a-vis* plan and actual achievements and consequent escalation in cost
4. Rising cost of fossil fuels as inputs into thermal power plants
5. Environmental concerns regarding fossil fuel burning
6. Limited resources of fossil fuels

In the mid-seventies, the government of India realized the need to develop hydro and thermal projects at its own initiative mainly to resolve inter-state disputes and expedite implementation of projects. In the State Power Ministers' Conference in August 1982, the union minister for Energy stressed the importance of developing micro-mini

¹ Supply and distribution of electrical power and water are state government subjects as per the policy adopted after independence.

hydro power in a big way to meet the local energy demands wherever suitable sites exist. The document of the Eighth Five Year Plan (1992-1997) proposed that the status of MMHP be upgraded in status and recognised as a critical area by allocation of additional funds to the Ministry of Non-conventional Energy Sources (MNES) for this purpose. Under this initiative, 30% of the available funds are to be used to develop mini/micro-hydro power in the hilly areas of India.

MMHP technology - state of the art

When an MMHP installation is planned for isolated mode of operation with no pondage, the installed capacity is decided on the basis of minimum flow. This results in minimum cost of generation. When it is planned to operate the MMHP installation in parallel with the grid, the installed capacity is decided on the basis of marginal cost. These two approaches for planning the installed capacity of MMHP systems have been universally accepted.

Sizing of project

The installed capacity is decided depending upon the discharge in the stream, head available, demand for power and availability of funds. Data for discharge in the stream and its variation through the year (flow duration curves) are not generally available in most cases. However, methods have been devised to arrive at reasonable estimates of the same. Normally the project is designed for the minimum discharge that is expected during the year. The next step involves the determination of the number of units. It is generally expedient to have all the units of equal size and limit the number of units as far as possible to not more than three. Single unit installations have the disadvantage of total loss of power generation in case of unit break down which may not be tolerable in case of autonomously operating units.

In some cases, there is a tendency to install units of different capacities to suit the pattern of discharge variation in the stream or demand characteristics. This, however, requires multiple sized auxiliary machinery and maintenance infrastructure thus resulting in an increase in inventory. Such a choice is only desirable if there is a substantial accrual of benefit in terms of increased energy production which can off-set the increased cost of inventory. Sometimes use of dissimilar unit sizes can be justified if similar types of units are being used in some other nearby power stations in a cluster development approach.

State-of-the-art components of MMHP plants

A MMHP project broadly has two components: civil works and electro-mechanical works. A major share of the investment is for civil works and details of planning and design vary to suit site conditions. Discussed below, are details of some of the most common components used in India.

The diversion structure

The diversion structure may be a dam or a weir. The construction of a dam for a micro hydel scheme could be expensive. The best solution would be to avoid the construction of any structure on the river bed by making arrangements to collect the water for power generation below the river bed. This is done by the help of a trench type weir. The trench type weir consists of trapezoidal trough located below the bed of the river. Trash racks are put at the bed of river to stop the boulders falling into the trench.

In comparatively small streams however, the water can be diverted during lean season by constructing a low cost barrier. This could be made of boulders, wooden planks, or mud-clad tree branches. The barrier is allowed to get washed away during flood letting the boulders and sand be carried by river to flow down stream. Intake level, etc., however, should be so designed that sufficient water for power generation flows in the intake during flood condition even without barrier.

On one side of the weir, intake structure and gated desilting tank is constructed. The gate provided at the intake structure is used to control the flow of water in the channel and gate provided in the desilting tank is used to remove the silt from the bottom of the tank. Intake gates could be of simple design made of steel plate or wooden plank with manual hoisting arrangements.

Water conductor system

Water conductor system may comprise open channel, cut or covered, penstock, etc. Location of intake and power house should be so chosen that the length of water conductor system is minimum. Open channel should be used if the soil and geological formations along the channel route are stable. Channel can be lined or unlined. Lined channel would prevent seepage. To reduce the cost, however, the possibility of using unlined channel should be examined. In some stretches if the channel construction is difficult, steel plates, GI sheets, or wooden flumes could be used. If stretches of channel where hill slopes are not stable and chances of landslides exist, RCC pipes or even steel pipes could be used.

Penstock

Penstock could be made of PVC, wood, RCC or steel pipes. PVC and wooden penstocks have been used in some countries. In India, however steel pipe penstocks have generally been used since they require minimum maintenance. For steel penstocks, welded steel pipes or spirally welded pipes could be used economically which are available as ready stock. Circumferencial joints can be made at site. Expansion joints in the penstock can be eliminated altogether when they are buried. Use of RCC pipes for penstocks could

also be explored. These pipes can be buried in ground to avoid the risk of breaking due to land slides. Cost of transportation pipes is the main consideration in deciding the use of RCC pipes.

Forebay desilting tank

Desilting tank, forebay and other civil structures should be constructed with maximum use of locally available material to keep the cost of construction low. The desilting tank and forebay can be made of steel tank, wooden tank or of RCC construction. The capacity of the forebay should normally be sufficient for diurnal storage so that evening peak loads are met. In hilly terrains, however, this may be a very costly proposition. On economic considerations, however, storage is designed for shorter periods. As per CEA guidelines a minimum of 2 minutes of storage has been recommended for the design of forebay tank. The maximum particle size permitted in the turbine is 0.2 mm for high head and 0.2 to 0.5 mm for medium/low head.

Hydro turbines

The hydro turbine is the key element of an MMHP station whose performance determines the techno-economic success of the station. Further, the size of the powerhouse depends upon the diameter of the turbine-runner. Hydro-turbines can be classified into two broad generic types, namely, impulse and reaction, with further variations. The salient features of some important types of turbines.

The Pelton turbine. It is one of the oldest turbine designs and is based on the principle of water wheel. The turbine is generally preferred for relatively high head applications. In a Pelton turbine, one or more jets of water impinge on a water wheel containing many curved buckets. The jet stream is directed inwardly, sideways and outwardly thereby producing a force on the bucket which in turn results in a torque on the shaft. This turbine is usually very efficient, particularly at high heads.

Turgo-impulse turbines. The turgo impulse wheel was specially designed for application in micro and mini hydroelectric stations with a specific speed intermediate between the Pelton wheel and Francis turbine. It is generally suitable for medium heads where higher rotational speeds coupled with the advantages of impulse wheel, that is, higher part-load efficiencies are desirable. In this turbine, there is a higher axial thrust developed due to asymmetrical shape of the wheel buckets which is taken care of by an appropriately sized thrust bearing.

Cross-flow turbine. The cross flow turbine is approximately a 90% impulse and 10% reaction turbine which is suitable for micro and mini hydro applications due to its simple constructional features, higher part-load efficiencies which are almost flat over

a very large portion of its operating range (from nearly 15% to full load), and self cleaning properties. As it can be manufactured even in small workshops with normal fabrication facilities, it has found extensive application in developing countries. Its simple construction makes its maintenance easy even in remote areas.

Francis turbines. Francis turbines are reaction turbines having a mixed flow type runner with both, radial and axial flow components. Unlike impulse wheels which utilize the kinetic energy of the impinging water, Francis (Reaction) turbines utilize the pressure drop across the rotating passages. This implies that the entire flow passage from the inlet to the tail race should be filled.

On the whole, Impulse turbines tend to be efficient over a relatively narrow range of specific speed whereas Francis and propeller turbines have a wider useful range. In relatively unsophisticated turbines having fixed gate and blade settings, the efficiency tends to drop off as the load becomes progressively lesser.

Generator

The generator is coupled to the turbine either directly, or through speed increasing gears or through belt-pulley drive for smaller units usually less than 100 kW. Speed-increaser enhances the rotational speed of the generator, thereby reducing its size and consequently the cost.

The generators could be synchronous or asynchronous types. Synchronous generators have their own excitation system whereas the asynchronous ones (induction generators) have to depend on external sources like utility power supply system for providing power to the field coils. Thus, synchronous generators are more sophisticated and versatile in application though more expensive. Induction generators operating under part load conditions have low power factor which may cause additional burden on the power system unless there is adequate capacitive compensation. In short, induction generators are ideally suited for operation in parallel with the utility system and preferably at near full load. However there should be a suitable source of power available for providing power to the field coils. The largest induction generator installed so far is of 5 MW size.

The hydro-turbine driving induction generators requires simple controls for starting, loading and stopping, whereas an elaborate system including synchronisation facility is required when driving synchronous generators. For isolated operation, synchronous generators are preferable, because they outweigh the induction types on cost terms.

Selection of hydro-turbine

Selection of an appropriate type of turbine is based on the considerations of site conditions, namely, head and head variation, discharge and discharge-variation and load variation. The turbine which meets the performance requirements and with the maximum net annuitised benefits, is the most appropriate type. Each type of turbine has an operating range over which its performance is technically acceptable. Charts for turbine application have been developed by many of the manufacturers indicating the head and discharge ranges over which a particular type of turbine is more appropriate than others.

For determining the diameter of runner, all the manufacturers have developed charts showing the output characteristic of each standard runner diameter as a function of head and discharge. The runner diameters have been standardized by each manufacturer and may vary from manufacturer to manufacturer. Similarly their performance characteristics may also vary as design considerations may be different. Therefore the selection of appropriate turbine and runner diameter is based on the considerations of least cost of production of electrical energy at the particular site. In India, mostly Turgo-impulse and Francis turbines are preferred.

Axial setting of a turbine

The Pelton, Francis and Propeller type turbines are essentially same whether used in small or large hydroelectric stations excepting for their axial setting.

The turbine-generator axis arrangement in a hydropower station can be either vertical, horizontal or inclined. The vertical axis arrangement is adopted universally for the medium and large hydropower stations and the horizontal axis arrangement for MMHP stations.

Status of the Indian MMHP Programme

The entire MMHP programme used to be under the administrative control of the Ministry of Power with individual state electricity boards having the responsibility of execution and maintenance. However, as MMHP grew in importance over the years, the need to provide sharper focus also grew and thus, the job of handling administrative and policy matters concerning MMHP projects upto 3 MW capacity was entrusted to MNES in early 1989. Subsequently, efforts have been made by the Ministry to reduce the costs through bulk purchases, thereby achieving volume effect. This approach was necessary in order to enable the equipment manufacturers to gear up for manufacture, supply and commissioning MMHP systems at competitive prices with reasonable profitability. Another significant item wherein cost reduction was attempted was civil works wherein there is substantial scope for rationalization. The approach has been to avoid large by-pass channels, layout design for minimal cost, increasing available head by combining adjoining drops, simplification of civil design, etc.

In addition to this approach, MNES is interacting closely with electricity boards, state nodal and other implementing agencies, equipment manufacturers, consulting engineers, etc. The efforts have given rise to a clearly laid out programme for encouragement of MMHP in the country. The objectives and sub-objectives of the MNES programme are as follows.

Objectives of MNES programme for MMHP

- To promote speedy development of micro, mini and small hydel schemes of upto 3 MW capacity for power generation in order to be able to utilize the available potential to its fullest extent.
- To achieve 600 MW worth of installed capacity in terms of MMHP during 8th Plan (1992-97).

Sub objectives

- To provide electricity through MMHP for cooking/lighting and other domestic requirements of the people residing in remote hilly regions.
- To help in protecting and ameliorating the environment by checking deforestation and by catalyzing a change in the fuel usage practices of people residing in hilly areas towards the use of electricity in place of firewood.

- To create suitable conditions for private sector participation both in setting up and subsequent management of MMHP projects. The promotional incentives would feature assistance or co-operation for wheeling, banking and purchase of power from private sector.
- Standardization of E&M equipments and simplification of civil design to achieve reduction in costs.
- Supporting R&D development and new technologies suiting Indian conditions.

Institutional arrangements and facilities from Govt. of India

To fulfil the above listed aims and objectives, a number of schemes have been formulated by the MNES. The schemes are designed to attract private investment in the sector and expand the prospects for MMHP. Some of these schemes have been discussed later in the report.

Achievements

Table 2 shows the state wise achievements with respect to the installed capacity under MMHP projects. The total installed capacity of MMHP in India is about 106.5 MW and about 198.2 MW is under construction. It can be seen that bulk of the MMHP installed capacity is in the states of Uttar Pradesh, Arunachal Pradesh and Himachal Pradesh.

Table 2: State-wise List of Installed MMHP upto 3MW capacity (as on 31.3.93)**

Sl. No.	State	Projects installed		Projects under construction	
		No.	Capacity (MW)	No.	Capacity (MW)
1	Andhra Pradesh	4	3.01	8	9.15
2	Arunachal Pradesh	25	16.75	15	19.75
3	Assam	1	2.00		
4	Bihar			1	1.00
5	Goa			2	2.90
6	Gujarat			1	2.00
7	Haryana	1	0.20	1	0.10
8	Himachal Pradesh	13	9.17	4	8.30
9	Jammu & Kashmir	5	2.31	5	5.40
10	Karnataka	1	0.40	3	1.39
11	Kerala	2	0.02	7	14.50
12	Madhya Pradesh	2	1.20	7	9.05
13	Maharashtra	3	3.58	4	6.20
14	Manipur	4	2.60	5	4.70
15	Meghalaya	1	1.51		
16	Mizoram	8	3.36	3	8.00
17	Nagaland	5	3.17	4	5.50
18	Orissa	1	0.50	8	10.5
19	Punjab	4	3.30	4	4.20
20	Rajasthan	2	0.82	5	4.91
21	Sikkim	6	6.90	2	2.40
22	Tamil Nadu	2	2.75	1	2.00
23	Tripura	2	1.01		
24	Uttar Pradesh	36	22.27	35	26.20
25	West Bengal	5	7.46	1	1.20
	Total	145	106.65	159	198.42

** As per available reports of different SEBs/Agencies.

Programme evaluation

The TERI team had visited a few selected sites in the states of Uttar Pradesh, Himachal Pradesh and Arunachal Pradesh to obtain feedback on the impact, effectiveness and constraints of MMHP technology in those regions. A detailed account on the case studies is given in another supplement of this report. The following sub-sections discuss, in general, the inferences from these studies.

Overall impact on energy scene

The overall impact has been observed to be different depending upon the region, its developmental status and usage pattern. Looking at the different states, the following picture emerges:

Uttar Pradesh

This hilly region of this state has traditionally remained relatively backward and relied more on power generated in the plains. The Uttar Pradesh State Electricity Board has installed a number of mini and micro hydel powerhouses at various places to augment the energy supply position. It was observed that the down time was quite high and for a substantial part of the year, the grid back-up had to be resorted to. Since some of the powerhouses did not run in parallel with the grid (i.e., they worked in decentralized mode), the load factor was very low. Domestic use being the major contributor of connected and peak load (in absence of any major industry), the peak load timings were very short. Thus the unit tends to remain underloaded for a large part of the day. Due to these factors, the Board officials tend to rely more on power supply from the grid network.

Himachal Pradesh

In this state, there is a very extensive grid network and almost the entire state has access to the grid. Due to this, the load factor of the operating MMHP installations tends to be high. A major distinguishing feature of the Himachal Pradesh Electricity Board, which manages the power generation and distribution in the state, is that it is a profit making agency unlike many of its counterparts in other states. The state has a number of large hydro installations, the power generated from which, is much in excess of the requirements in the state and is sold to adjoining states.

Since the fixed costs involved with the installation of MMHP power plants and subsequently, the cost of generation from them is normally higher, the Board prefers to go slow on the implementation of these projects. This helps in keeping the margin of

profits high. However, feeding the generated power to the grid helps to keep the cost of generation to the minimum possible value.

Arunachal Pradesh

Arunachal Pradesh presents a very different scenario as compared to the other two states. Due to the relative inaccessibility of this state from the mainland and the coal belt, there had neither been any thermal power installation in the region nor had the grid been extended to the state. Since several years, the state has been relying upon diesel gensets for meeting the power demand. In fact, due to the low population density, there is no separate utility in the state and the power generation and distribution is being handled by the Department of Power.

Since the past few decades, a number of MMHP generating stations have come up in the state and in some areas, even a local grid network has come up. Again, due to absence of any major power consuming industries and enterprises, domestic demand is the only contributor to load. The older installations tend to remain inoperational for extended periods of time because of various technical reasons. Due to this there was a problem in meeting the peak demand. The newer installations like Tago hydel are giving better performance and are contributing greatly to improving the situation.

Considering the vast scope for MMHP in the state, it may not be difficult to transform it from a power purchasing state or a state relying in diesel to a power selling state. The North Eastern Electric Power Corporation (NEEPCO) is also taking up some large hydel installations in the state in a bid to utilize its immense potential.

Technical constraints and operational problems

In all the three states, the MMHP installations are facing a number of technical and operational problems. These are as follows:

Silt during monsoon

There is a major problem of silt ingestion during the monsoon season which seriously damages the turbine. The silt content in the stream during the rainy season tends to be so high that the normal desilting arrangement fails. Ingestion of the silt by the turbine causes extensive damage to the runners thus incapacitating the unit.

Damage to civil works

During the flood, there is also damage to the diversion structure and power channel. Particularly when the discharge in the stream is the highest, large boulders roll down the bed alongwith particles of almost all sizes. On most occasions, the diversion weir is

washed away or severely damaged. The power channel also gets damaged on several reaches. Landslides also contribute to damage of the power channel.

Operation of sluice gates

The sluice valves and gates at various places were found to be difficult to operate. Some of them were jammed due to defects in the threads and bending or mis-alignment of the rods. It seems necessary to re-examine the design of these structures and look into the possibility of improving their performance. This is important because inability to operate these in times of technical fault can lead to serious damage to the machinery.

Workshop facilities

Most MMHP installations are located in areas which are remote and relatively difficult to access. In case of technical failure, it is very time consuming and costly to transport the defective components to a competent workshop for repair. Similarly, it is equally costly and time consuming to transport raw material (cement, sand, etc) to the site for civil work. In this respect, it may be useful to set up one suitable workshop such a location which can be conveniently accessed from about five or six MMHP stations.

Institutional problems

There are a number of institutional problems which could perhaps be adversely affecting the performance of MMHP stations in the country. In Uttar Pradesh, for example, the Electricity Board does not have a civil wing of its own. The civil works are to be maintained by the irrigation department. Since the powerhouse is manned by the Board officials, they have to convey information about any work requirement in the civil works to the concerned official who may be located several hundred kilometers away and thus, unavoidable delays creep in. Priorities of the other department being different, the execution of the job depends upon factors such as preoccupations of their personnel, availability of manpower and priority jobs in hand. It may, therefore, be expeditious if the Board can have a civil wing of its own.

Policy review and future prospects

Potential

According to the latest figures being compiled by the Ministry of Non-conventional Energy Sources, the total small hydro potential for India upto 15 MW capacity has been estimated to be about 10,000 MW. About half of this is expected to lie in the hilly areas and the North Eastern region. The MNES, which is dealing with MMHP projects upto 3 MW while projects above 3 MW, is engaged in preparing the database for 1344 sites, the potential of which aggregates to about 1171 MW. Details about these are presently not available.

Table 3: Small hydro power potential assessment (Tentative results of studies)

Name of states	No. of schemes	Installed capacity (MW)
A. Northern Region		
Jammu & Kashmir	103	847
Himachal Pradesh	153	1225
Punjab	98	116
Haryana	2	8
Rajasthan	40	36
Uttar Pradesh	217	1073
Total	613	3305
B. Western Region**		
Gujarat	161	130
Madhya Pradesh	39	199
Total	200	329
C. Southern Region		
Kerala	76	403
Grand Total	889	4037

**** The studies for other states of southern region are in progress and the work for remaining states is yet to be taken up.**

CEA assessment studies conducted earlier in nine selected states have arrived at a figure for potential for MMHP in India of about 4037 MW. A detailed break-up of this potential has been shown in table 3. These figures are not the latest, however, it can be seen that expectedly, Himachal Pradesh and Uttar Pradesh have the maximum potential followed by Jammu and Kashmir. It is these very states except, perhaps, Himachal Pradesh that have a large demand for power, particularly in the domestic sector. Notably, figures for the North-eastern region are not available in the table.

New strategy and promotional schemes

Enumerated below are a few important promotional schemes of the Government of India prepared by the Ministry of Non-conventional Energy Sources.

Capital subsidy scheme

A subsidy scheme has been evolved by the MNES for the setting up of MMHP projects upto 3 MW station capacity during 8th Plan period. The salient features of the scheme are as follows:

- All projects upto 15 MW capacity to be taken up by private and also public sector organizations (other than SEBs, State Govt. Departments and loss making organisations) which qualify for the World Bank loan assistance, shall not qualify for MNES subsidy.
- The following will be the subsidy scheme of MNES in respect of all the MMHP projects upto 3MW capacity excluding the projects falling in above category:
 - *For grid connected projects:* subsidy upto 25% of the acceptable costs of civil works and E&M equipment including generator transformers.
 - *For non-grid connected¹ projects (irrespective of grid connected or non-grid connected in case of North-eastern or hilly regions):* subsidy upto 50% of the acceptable capital costs of civil works and E&M equipment including the transformers. Power from the MMHP projects not connected to the grid or in North-eastern region and hilly regions is to be sold at reduced rates reckoned on a cost of generation calculated after netting out subsidy element from the capital cost.

The above subsidy is to be provided for all kinds of projects irrespective of whether they happen to be set up by private, government or cooperative sectors. However, loss making private and public sector entrepreneurs will not be eligible for

¹ The projects are designated as non-grid connected if the grid transformer is in excess of 2 km from the project site.

grant of subsidy. No incentives would be provided, as mentioned earlier, for projects aided by World Bank or any International agency, requiring international bidding or tied supplies.

The following amounts have been approved as the acceptable capital cost of civil works and E&M equipment including generator and transformer for the purpose of providing the subsidy¹:

Broad category of projects	Capital cost/kW of E&M and civil works for provision of subsidy	
	Station capacity below 500 kW	Station capacity 500 kW and above
<i>Projects at canal drops/irrigation dam based sites:</i>		
(a) heads above 3 m	Rs 32 000	Rs 27 000
(b) heads below 3 m	Rs 36 000	Rs 32 000
Run of river projects in plain regions	Rs 38 000	Rs 34 000
<i>Projects in North-eastern regions and other hilly areas (as declared by state government)</i>		
(a) within 10 km. from road head	Rs 40 000	Rs 36 000
(b) between 10-20 km. from road head	Rs 45 000	Rs 40 000
(c) above 20 km. from road head	Rs 50 000	Rs 45 000

¹ The subsidy is restricted to the cost of E&M and civil works only as detailed in the table. If in any specific case, the actual cost of E&M and civil works happens to be lower than the above (approved) costs, the subsidy amount would then be computed in basis of the actual costs. All expenses over and above the subsidy element including escalations in the cost, if any, would have to be met by the promoters of that project.

Incentives for portable micro-hydel sets

A promotional scheme for light-weight portable micro-hydel sets for remote, hilly areas and North-eastern region of the country has also been announced. Its objectives and salient features are as follows:

- To promote and popularise MMHP development in the remote, hilly unelectrified areas of the country.
- To enable local bodies/communities or cooperatives to install, operate and maintain micro hydel sets to meet the local demand of power.

Scope and salient features

The scheme is meant only for areas which are unelectrified and not likely to be electrified in near future. These include hilly and inaccessible areas (as declared by state government) and the entire North-eastern region of the country. The intended beneficiaries are either local bodies/communities or cooperatives willing to own operate and maintain the hydel sets. NGOs may also be associated.

The scheme will cover distribution of light-weight portable sets of upto 15 kW generator output, including control panel and electronic load controller as per the following specifications:

- | | |
|-------------------------------------|---------------------|
| 1. Head | - above 30 meters |
| 2. Power rating | - upto 15kW |
| 3. Maximum weight of single package | - upto 300 kg |
| 4. Dimensions of largest package | - 1.25 cubic meters |

In the first phase, only 50 sets are intended to be distributed free of cost. Thereafter, following a review, the scheme may be continued, and the subsidy reduced in a phased manner.

Transportation cost of the sets upto the state head quarters will be covered by MNES under the scheme, and from the state head quarters to the project site will have to be borne by the state government/beneficiary. The beneficiary is expected to carry out all other works essential for completion of the project, including civil works, local distribution network, etc.

Composite promotional incentive scheme for detailed survey and investigation and preparation of Detailed Project Reports (DPRs) for MMHP projects upto 3 MW capacity.

The objectives of this scheme are as under:

- To accelerate MMHP development through systematic studies, scientific approach, and through better management of costs and project duration.
- To encourage work on survey and investigation and preparation of DPRs.
- To create a shelf of projects which will be very useful for standardisation for E&M equipment and civil designs, arranging financial package and where necessary induction of state-of-art technology.

Scope and implementation

The scheme is open to investor organisations in government, public, private, cooperative, non-government or joint sector. It is admissible both for work done in house or through hired engineering consultants.

Scale of incentives

Separate incentives have been framed for the two activities viz. (I) for undertaking detailed survey and investigation and (II) for preparation of DPRs. These are as follows:

Incentive for detailed survey and investigation. In the form of grant-in-aid at 100% support to actual cost incurred for detailed survey and investigation or as per the amount given below (whichever is less):

Broad category of projects	MMHP scheme potential (below 500kW)	MMHP scheme potential 500kW and above)
Projects at canal drops/dam toe sites	IRS 0.40 lakhs	IRS 0.75 lakhs
Projects at run of river sites in plain region	IRS 0.50 lakhs	IRS 0.85 lakhs
Projects in North Eastern region and other hilly areas (as declared by State governments)	IRS 1.00 lakhs	IRS 1.50 lakhs

Incentive for preparation of DPRs. In the form of grant-in-aid at 50% of the actual cost of preparation of DPRs or as per the amount given below:

Broad category of projects	MMHP scheme potential (below 500 kW)	MMHP scheme potential (500 kW and above)
Projects at canal drops/dam toe sites	IRS 0.40 lakhs	IRS 0.75 lakhs
Projects at run of river sites in plain region	IRS 0.50 lakhs	IRS 0.85 lakhs
Projects in North Eastern region and other hilly areas (as declared by state government)	IRS 0.65 lakhs	IRS 1.00 lakhs

Quality and time frame

- The survey and investigation reports and DPRs are to be carried out in conformity with **Guidelines for Development of Small Hydroelectric Schemes** laid down by CEA and other relevant standards/practices laid down from time to time by CEA/CWC/MNES.
- Duration of projects for detailed survey and investigations to be two lean season, or 18 months, and preparation of DPR to be maximum 6 months.

Soft loans through IREDA

The Indian Renewable Energy Development Agency (IREDA), a public sector undertaking under the Ministry, offers soft loan to private sector entrepreneurs for setting up of MMHP projects. World Bank loan of US \$ 70 million has been secured over and above IREDA's resources for this purpose. Details regarding these loans are as follows:

Eligibility

All MMHP projects upto 15 MW station capacity and 5 MW unit capacity, on irrigation dam/toe/canal drop based sites.

Loan limit

The loan amount is limited to 75% of total cost of project or cost of eligible items under World Bank loan, whichever is lower.

Interest rate

The interest rate will be 15.5% with rebate of 0.5% for timely repayments.

Repayment period

The repayment period is to be ten years, with a maximum moratorium period of 3 years.

IREDA has already financed 11 small hydro electric projects spread in four states of the country with a total installed capacity of 23 MW.

Fiscal incentives

The following fiscal incentives have been formulated with a view to promote investment in MMHP projects by the ministry:

- Power generation schemes involving capital outlays upto IRS 25 crores need no prior clearance from the Centre.
- Tax holidays as applicable for power generation as per recent budget announcement.
- Concessional customs duty @ 20%.
- 100% depreciation under income tax under consideration as already applicable to other NRSE systems.

Import policy

The import policy for procurement of equipment has also been restructured and import is being allowed in the following circumstances:

- Where the funding is tied to a foreign loan like World Bank Loan, etc., and the loan conditions dictate international competitive bidding.
- Where global tenders are invited and an imported offer is selected, the equipment could be subsequently manufactured in the country under a collaboration with the foreign supplier.

Assistance from UNDP/GEF

A proposal on "optimizing development of small hydro resources of hilly regions of India" has been agreed to in principle by the UNDP for technical grant assistance of US \$7.52 million under its global environment facility fund. The objectives of the programme include: implementation of demonstration projects; development of appropriate technologies; and the formation of a national infrastructure for optimal implementation of MMHP sites in the hills. The programme will attempt making a Master Plan for the entire Himalayan and sub Himalayan region from J&K to Arunachal Pradesh; install some 20 priority demonstration projects in 3 different pilot project areas; upgrade some 500 water mills to generate 1-3 kW power from each; and in general, prove the techno-economic environmental superiority of small hydro in reducing carbon

emissions (and thereby global warming) by providing electricity for cooking and heating purposes, etc.

Avenues for Private Investment

The following benefits of MMHP can be attractive to private investors who would like to examine this option as a profit making venture:

- Profitability decided once and for all by the choice of equipment, type of financing and legal set up.
- Limited initial investments.
- Short gestation periods.
- No recurring fuel costs; no consumption of valuable raw materials; low operational and maintenance costs.
- Faster return on investment - net cash flow within 5 years, against plants' life span of over 30-40 years.

Based on this the following arrangements are being made up to enhance the scope for participation for private entrepreneurs:

- State Electricity Boards and other concerned State Nodal Agencies allowed to lease out MMHP sites to private sector entrepreneurs/industrial units for power generation for either captive use or public distribution.
- Arrangements for wheeling, banking and buy-back of power. Terms already announced by some states and under finalisation by others.
- Soft loans through IREDA/World Bank.
- MNES subsidies for private sector projects not qualifying for IREDA/World Bank loan.
- Incentives also extended for upgradation of water mills into small electricity generation units in private sector.
- Encouragement to voluntary agencies and local communities to start take over and manage MMHP projects in remote areas.

Recommendations

Overview of state-of-the-art

Most of the components used in a MMHP installation are not very sophisticated and can be manufactured in the country itself. Only the turbine runner and casing and perhaps, the shafts require some amount of precision in manufacture and stringent quality control. The country has sufficient experience in electrical and heavy electrical equipment. Already, a number of manufacturers of such equipment have come up and have supplied their systems to a number of user agencies. Mostly, Turgo impulse and Francis turbines have been found to be useful under Indian conditions. Similarly, sufficient expertise exists in the country for siting and DPR preparation.

What is important, however, is the skill with which these components are integrated. Particularly, the alignment of the penstock with the generating equipment, governor installation, etc. need to be given extra attention. As discussed earlier, the design and operation of the sluice valves needs to be looked into closely so as to find out the possibilities for improvements. More effective methods need to be developed for desilting of flowing water, particularly during the monsoon. On the whole, it can be said that though the state-of-the-art technology is good, some fine tuning is required in the overall design set-up to make the technology more suitable to the local conditions.

Recommendations

Following are the recommendations, grouped in various categories, which evolve from the experiences in this study:

Thrust areas, R&D and avenues for cascade development

The major focus for development of mini-micro hydro in India should be on suitably refining the present designs to suit local conditions and encouraging manufacture of quality equipment. Private parties should be encouraged to come forward and invest in this sector. The following suggestions may be useful in achieving the same.

- Steering committees should be constituted at central and state levels to plan strategies to bring about accelerated growth of MMHP programmes in their respective regions.
- Concerned agencies in states should keep ready a number of schemes on the shelf to be offered to private developers; for these schemes, statutory clearances like techno-economic, environmental forest clearance, etc. should have been obtained.

- Model layouts as prepared during preliminaries of MNES/AHEC should be given to the developers to give them cost effective designs.
- Adequate human resource development effort should be undertaken in respect of design and execution of small hydro projects.
- R&D work should be initiated to evolve low cost, durable and trouble free designs as well as construction methods. Particularly, due attention should be given to the design of sluice gates and valves as these are essential components for smooth functioning of the project and for having full control over the operation of the machinery.
- A design and research institution should be set up at the national level for evolving appropriate technology for setting up small hydro stations. This institute could also take up the job of imparting training to operating personnel for such stations.

Institutional aspects

There are a number of institutional and implementational aspects that need to be looked into and refined to give a boost to the MMHP programme in India. They include the kind of institutional structure that exists, the concerned agencies that exist at the centre and state levels and the discursive nature of formalities or procedures that have been devised for parties interested in this field. These can be summarised as follows:

- A separate organisation should be formed in each state with adequate funds and necessary statutory powers to plan, investigate and develop small hydro effectively with private participation.
- Centres should be established on zonal/cluster basis to provide maintenance and repair services at reasonable cost.
- A working group should be formed to provide guidelines for obtaining clearance from the Ministry of Environment and Forests, for small hydro projects. For example, the procedural formalities involved in the following could be simplified:
- As per existing regulations, techno-economic clearance for a scheme costing more than Rs. 25 crore has to be referred to the Central Electricity Authority. This could, instead, be vested in the state authorities themselves.
- Under FL Act 1980, clearance is necessary from the Government of India in case of forest lands are required for implementation of projects irrespective of the extent of forest area. Rather, states should be empowered to accord clearances for MMHP projects requiring forest lands upto 10 acres.

- Small hydro upto 3MW should be exempted from environmental clearance. Environmental clearance of small hydro in the range 3-15 (or 25) MW should be scrutinised in simpler format across the table.
- A single window clearance agency should be formed at state level on the lines of the one constituted in Karnataka.

Economic and financial measures

Financial assistance and incentives can go a long way in accelerating the growth of MMHP in the country. Already a number of incentives are being offered to interested parties for setting up of MMHP based generating stations. Enumerated below, are some more such measures that could be considered for adoption. These have been compiled from a number of sources including feedback from manufacturers.

- Loan assistance extended by IREDA should be available for schemes of capacity upto 75 MW instead of restricting it to schemes of 15 MW capacity. This assistance should cover the entire cost of the scheme and should not be restricted to the cost of equipment.
- Adequate relief should be provided to private developers in respect of customs duty, sales tax, octroi duty, electricity tax, etc.
- The wheeling and banking charges payable to electricity boards for different categories of small hydro should be of the order of 2%, 5%, and 10% respectively in the case of MMHP projects upto 3 MW, 3-5 MW and 5-25 MW capacity.
- Soft-term loans on the cost of civil works which works out to around 40-50% of the total project cost should also be provided to private developers on easy terms.
- The cost to be reimbursed by private developers in respect of feasibility studies should be 1-2% of the total cost of the scheme, which can be financed by way of subsidy by the lending institutions.
- Projects in remote areas like Northeast and other high altitude and remote areas should be treated as a special category and dealt with separately for financial assistance.

People's participation

Involvement of the beneficiaries of the project right through the implementational stages of the project definitely plays an essential role in its ultimate success. It is desirable to earn goodwill of local people and ensure their involvement through activities such as literacy drives, creation of essential facilities in villages and creation of job opportunities

for local people at site. Local panchayats and societies should be encouraged to operate and manage micro/mini stand-alone units (say upto 500 kW) for on their own.

Operational and other factors

Any power project tends to work at a much better load factor when connected to the grid. The grid network acts as a buffer which helps in evening out the fluctuations in load. Naturally, the larger and more extensive the grid network, the more effective it would be in utilizing the power produced at the powerhouse. However, there are high costs involved in extending the network to remote areas over difficult terrain. In view of this, it is recommended that wherever possible, the grid should be extended. Even local grids could be developed in case of remote locations in a way such that three to four MMHP stations feed into them.

There is debate from a few quarters on the environmental benign character of MMHP projects. Perhaps sample case studies conducted for say 3, 5, 10 and 15 MW installed capacity with regard to environmental assessment may help to arrive at

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Appendix 1

List of consultants engaged in small hydro power development

A. Consultancy organisations (Govt./Semi-Govt./Autonomous Bodies)

1. Alternate Hydro Energy Centre, University of Roorkee, Roorkee 247 667. Phone: 01332-72349, 72130 extn. 313, 213, 673, Fax: 01332-73560, 73517, Gram: ENERGYCENTRE, telex: 0597-201 UOR IN
2. Balmer Lawrie & Co. Ltd. (Energy Division), 21, Netaji Subhash Road, Calcutta 700 001. Phone: 033-20671, Fax: 033-283768, Telex: 021-2341, 7435, Gram: BALMER
3. Central Board of Irrigation and Power, Malcha Marg, Chankyapuri, New Delhi 110 021. Phone: 011-3015984, Fax: 011-3016347, Gram: CENBIP (ND)
4. Energy Management Centre, 118, Ashirwad Complex, D 1, Greem Park, New Delhi 110 016
5. Water & Power Consultancy Services Ltd., 5th Floor, Kailash, 26, K.G. Marg, New Delhi 110 001. Phone: 011-331-3131-4, Fax: 011-331 6403, Telex: 31-61961 WAPIN, Gram: WAPCOS,
6. Water Resources Development Training Centre, University of Roorkee, Roorkee 247 667. Phone: 01332-72349 Extn. 5774, 5775, Fax: 01332-73560, Gram: WATERRESOURCES

B. Consultancy organisations (Private)

1. BIP Consultants Pvt. Ltd., V-136, Shakarpur, New Delhi 110 092
2. Consulting Engineering Services (India) Pvt. Ltd., Manjusha, 5th Floor, 57, Nehru Place, New Delhi 110 019. Phone: 6427159, 6460411, fax: 011-6460409, Telex: 31-62678, Gram: CONSENGER
3. Consolidated Energy Consultants Pvt. Ltd. 27, M.P. Nagar, Zone II, Bhopal-1, Madhya Pradesh.
4. Development Consultants Ltd. 24-B Park Street, Calcutta 700 016.
5. Desein SNC Pvt. Ltd., Desein House, G.K. II, New Delhi 110 048.
6. Engineering & Management Consultants (EMCON). 11, Rahulkunj Coop Housing Society, 61A, Rambag Colony, Near Chailanya Health Club, Off. Paud Road, Pune 411 038. Phone: 0212-346927, Fax: 0212-331250, Telex: 145-7555 IN.

7. **Engineers Constructions (P) Ltd., F-463, Sarita Vihar, New Delhi-110049. Phone: 011-6833000, Fax: 011-6849573, Telex: 31-75260 BABA.**
8. **Engrs. & Consultants Inc., 40/903, Mullassery, Opp. College Ground, M.G. Road, Ernakulam-682011. Phone: 364613.**
9. **Haq Consultants, "Baitul Fazal", 2527, Agra Road, Jaipur-302003. Phone: 0177-40588, Telex: 0365-2442 HAQ-IN, Gram: CONSORTIUM.**
10. **Hydel Equipments, G.S. Road, Bhangagarh, Guwahati-781005. Phone: 0361-563860, Telex: 0235-2421, Gram: INCONSUL.**
11. **Mekaster Consultants Pvt. Ltd., Lal Bhawan, B-84, Okhla Industrial Area, Phase II, New Delhi-110020.**
12. **Premier Energy Technologies Pvt. Ltd., Nehru House, 4 B.S.Z. Marg, New Delhi-110002.**
13. **Premier Engg Group, C-4, Navratra Apartments, 56, 17th Cross, Malleswaram, Bangalore-560005. Phone: 080-311427.**
14. **Tata Consulting Engineers, 73/1, Street Mark's Road, Bangalore-560001. Phone: 080-214721, Telex: 0845-2463, Fax: 80-214873.**
15. **Technology & Research Associates, 5, Lindsay Street, Calcutta-700087.**
16. **Thapar Hydro Consultants, 26, Community Centre, Basant Lok, Vasant Vihar, New Delhi-110057. Phone: 608319, Gram: THAPAGENT, Telex: 31-65112/62645, Fax: 011-3327729/6877902.**
17. **Reynold's Consultants, Care Home Complex, Bamuni Maidan, Guwahati-781021. Phone: 0361-550202, Fax: 0361-550202.**

C. Individual Consultants/Experts

1. **Shri A.N. Singh, (Retd. Chairman-CEA), K-2, Green Park, New Delhi-110016. Phone: 2217765.**
2. **Shri Bhagwan Prasad, Shakti, Dr. Bhattacharya Road, Patel Nagar, Patna-800023. Phone: 287407.**
3. **Shri C.R. Bhattacharya, 6, Old Post Office St., Basement Room No. 23, Calcutta-781021.**
4. **Shri C. Rama Rao, B-179, Lok Vihar, Pitampura, New Delhi-110034. Phone: 7183293, 7184456.**
5. **Shri S.N. Phukan, 15, La-Chaumiere, Shillong-793001.**

6. Dr. N.K. Bansal, B-1/23, Janakpuri, New Delhi-110058.
7. Shri V. Sreenivasa Murthy, (Retd. CE-KPCL), No. 18, 20th main Road, II Block, Rajaji Nagar, Bangalore-560019. Phone: 080-324609.
8. Shri Y.K. Murthy, Ex-Chairman CW & PC, D-44, Gulmohar Park, New Delhi-110049. Phone: 011-6865534.
9. Shri D.S. Rao, Consultant, Water Resource (I&P), X-29, Hauz Khas, New Delhi-110016.
10. Shri A.K. Shah, Chairman, Premier Energy Technologies Pvt. Ltd., Nehru House, 4 Bahadurshah Zafar Marg, New Delhi-110002.
11. Shri C.M. Jain, BIP Consultant Pvt. Limited, V-136 Shakar Pur, Delhi-110032.
12. Shri D.K. Basu, Consulting Engineering Services (India) Pvt. Ltd, 57, Nehru Place, New Delhi-110019.
13. Shri D. Kedia, Industrial Consultant, A.T. Road, Guwahati.
14. Shri H.O. Nanda, Matronics India Pvt. Ltd., 41/1, Ashok Nagar, New Delhi-110 018.
15. Shri Inamul Haq, Chairman, M/s Haq Consultants, "Baitul Fazal", 2527 Agra Road, Jaipur 302 003.
16. Shri J.C. Gupta, Retd. Chairman, UNSEB, D-1/52, Bharti Nagar, Khan Market, New Delhi 110 003.
17. Shri M.R. Moorthy, Hydrel-Tech. (Engrs. & Consultants), 185 G, Panampilli Nagar, Cochin, Kerala.
18. Director, Energy Management Centre, 118, Ashirvad Complex, D-1, Green Park, New Delhi-110016.
19. shri R.C. Mahulkar, Engineering & Management Consultant (EMCON), 61 A Rambag Colony, Near Chaitanya Health Club, Off Paud Road, Pune-411038.

Appendix 2

Manufacturers of small hydro-power equipments

Manufacturer	Head Range (m)	Type of Turbine	Type of Generator	Rating (kW)	Scope of Supply
in & Turbo Ltd. Park Plaza, 71 Park Street, Calcutta 016 Ph: 293251, 295568 Telex: , 5306, Fax: (033) 295534, Gram: APLANT	upto 10 3-10 5-25 26-200 200-400	Pair type Francis open flume S - Turbines Francis (spiral casing) Pelton double jet	N/A	N/A	Turbine
ib Power Generating Machines Ltd 108-109, Sector 8-C, Chandigarh 018 e: 29025, 42782 K: 395-484 PPJM IN 0172-32826 n: PUNPOWER	3-25 5-200 100-400	Tubular Francis Pelton	Induction Synchronous	Upto 3000	Turbine Generator, Gear Box, Complete E+M works for turnkey execution
Industrial Kerala Ltd. Nagar, Athani P.O. mgunnathukavu Thrissur, Kerala 680 ne: (048795) 335, 380 x: 0887-258 SILK IN (0487) 40511-PCO n: SILKATHANI	1-30 10-300 80 & above (upto 100 kW demo units)	Kaplan Francis Pelton Cross-flow	Induction Synchronous	Upto 1000 Upto 3000 & above	Turbine Generator, Gear Box, Control Panels and turnkey execution
Triveni Engg. Works Ltd. B6 Okhla Industrial Area, Phase I, Delhi 110 020 ne: 6811878 x: 031-75154 PAE IN (011) 6812280, 3310117 n: TEWPEDCO	1.8-5 5-8 10-130 5-15	Kaplan with Syphon intake Bulb Francis Pressurised Vertical Kaplan	Induction Synchronous	50-1500 200-3000	Turbine Generator Gear Box, Control Panels and turnkey execution
con Neyrpic Ltd. Industrial Estate (North) Jettur, Madras 600 098 ne: 655391, 651541 x: 041-22071 : (044)456223 m: CROMBEST	2-6 6-30 10-200 100-1000	Siphon Kaplan Francis Pelton	N/A	N/A	Turbine
rat Heavey Electricals Ltd. ani, Bhopal 462022 ne: 546100, 540200 x: 0705264, 265 (0755) 540425 m: BHARATELEC	3-16 15-500 4 16-25 45-180	S type tubular V Pelton Bulb V Kaplan H Francis	Induction Synchronous	Upto 3000 & above	Turbine Generator, Gear Box, Control Panels
ing Fourcess (P) Ltd. No. 7, KIADB Industrial Area -41, Hoskote galore 562 114 ne: 263/455 x: 0845-5086 (0812) 395176 n: FOURESSCOP	Upto 30 Upto 30 20-300 Above 200	Full Kaplan Semi Kaplan Francis Pelton	Induction Synchronous	1000 Above 1000	T.G. Unit, Complete E+M equipments for turnkey execution
rel Pvt. Ltd. 19 Okhla Industrial Area, Phase I, Delhi 110 020 ne: 6818036, 6813587 x: 031-75100 FLOV IN m: FLOVIN	2-20 3-10 15-300 90-400	Tubular/Pit Francis Open Flume Francis Pelton			Turbine, Gear Box
id Ltd. Industrial Area, P.O. Chemical Industries, odara 390 003 ne: 320041, 321038 x: (0265) 320766 m: PROJYOTI	2-25 25-30 45-180 50-200 100-400	Tubular Kaplan Francis Turgo-impulse Pelton	Induction Synchronous	Upto 50 upto 3000 & above	Turbine Generator, Control Panel, BF valve

Information not available
not manufactured